GUIDANCE NOTES
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INTERNATIONAL SHIP CLASSIFICATION

GUIDELINES FOR DIRECT PREDICTION OF ACCELERATION RESPONSE OF CONTAINER SHIPS

2024

Effective from 1 January 2025

CONTENTS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Objective

1.1.1.1 The objective of the Guidelines is to provide a direct calculation method for the acceleration response of container ships during navigation. The accurate prediction of acceleration borne by containers provides the necessary technical basis for formulating and implementing ship operational limitations, reducing the loads on the cargo stowage system and the incidences of containers lost at sea.

1.1.2 Application

1.1.2.1 The Guidelines may be applied to sea-going container ships of not less than 24 m in length.

1.1.2.3 Ships complying with the relevant requirements of the Guidelines may apply for the issuance of document of compliance.

1.1.3 Definitions

1.1.3.1 Unless expressly provided otherwise, the definitions of the Guidelines are as follows:

(1) Container ship: means a ship which is constructed specifically for the loading of containers in the cargo hold and on the deck.

(2) Tank test: refers to the model test of the ship's motion response in waves carried out in the tank.

(3) Wind tunnel test: refers to the model test carried out in the wind tunnel to determine the ship's wind heeling moment.

(4) Numerical calculation: refers to computer-aided hydrodynamic calculation, using modern computational fluid dynamics (CFD) software/program to solve. Software/program can be based on potential flow theory method or viscous flow theory method. The methods or numerical models used in the numerical calculation may be accepted as equivalents to the tank test provided that they have been verified by the tank test results.

1.1.4 Plans and documents

1.1.4.1 The following plans and documents are to be submitted to ISC for information:

(1) Lines and offset of the ship;
(2) General arrangement of the ship;
(3) Loading manual of the ship;
(4) Container stowage arrangement;
(5) Structural plan of bilge keel (if applicable);
(6) Direct assessment report of container ship acceleration response;
(7) Manual of sailing operational limitations to prevent the loss of containers at sea (if applicable);
(8) Onboard software and related documentation on sailing operational limitations to prevent the loss of containers at sea (if applicable).

CHAPTER 2 DIRECT PREDICTION METHODS OF ACCELERATION RESPONSE

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 In order to accurately predict the acceleration borne by containers carried by container ships, the large acceleration responses of container ships that may be produced by different motion modes during voyage at sea is to be assessed.

2.1.1.2 Direct assessment of acceleration response may be performed by tank test or numerical calculation.

2.1.2 Motion modes

2.1.2.1 When a container ship is sailing at sea, the motion modes that may result in the incidences of containers lost under the action of wave loads include:

(1) harmonic rolling motion;
(2) parametric rolling.

2.1.3 Effects of acceleration on container loads

2.1.3.1 The motion response of a container ship will cause the containers it carries to be subject to three types of acceleration, including: lateral acceleration parallel to the deck, longitudinal acceleration parallel to the deck, and vertical acceleration perpendicular to the deck. The deck plane is assumed to be a hypothetical plane without considering the effects of camber and sheer.

2.1.3.2 The lateral acceleration directly affects the torsional force and lashing force, and has an important effect on the container loads. It also increases the moment of transverse load when calculating pressure and separation force. Lateral acceleration is to be accurately assessed to determine the actual loads on the containers.

2.1.3.3 The vertical load caused by vertical acceleration increases only when the pressure is calculated, and decreases the load when the separation force is calculated. Vertical acceleration can generally be simplified to a fixed value, preferably the acceleration of gravity.

2.1.3.4 The effect of longitudinal acceleration on load is much less than that of lateral acceleration, which can be simplified to a fixed value or be ignored.

2.1.4 Loading conditions of the ship

2.1.4.1 The acceleration responses at the typical position of the containers are to be assessed under typical loading conditions when the ship is subjected to harmonic rolling motion and parametric rolling. Typical loading conditions may include loading conditions with a combination of several displacements, initial metacentric height (GM), trim and roll moment of inertia within the permissible range of loading conditions and are to include loading conditions with at least the maximum and minimum GM values. This can be supplemented by assessing specific actual loading conditions as needed.

2.1.4.2 The acceleration responses of containers for each loading condition at a typical height in a typical arrangement on the deck side of the ship are to be assessed.

2.1.5 Environmental conditions

2.1.5.1 Long crested irregular waves are to be used for assessment, with the wave spectrum as follows:

$$S(\omega) = \frac{H_s^2}{4\pi} \cdot \left(\frac{2\pi}{T_z}\right)^4 \omega^{-5} \exp\left(-\frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4 \omega^{-4}\right)$$

where: S——ocean wave spectral density function;

ω——frequency, in rad;

H_s——significant wave height, in m;

T_z——mean zero-crossing wave period, in s.

2.1.5.2 The mean zero-crossing wave period may be taken as 6.5 s to11.5 s, and the period step as 1 s. The range of significant wave height calculation may be determined according to the environmental conditions of the navigation area and the ship length. The wave height step may be taken as 1.0 m. The recommended calculation range is as follows, which may be increased or decreased according to the ship length as appropriate:

(1) For ships with a length greater than 250 m, the significant wave height may be taken as 3.5 m to 6.0 m;

(2) For ships with a length less than 200 m, the significant wave height may be taken as 2.5 m to 4.5 m;

(3) For ships with a length of 200 m and above but not greater than 250 m, the lower limit of the significant wave height may be taken as 2.5 m, and the upper limit of the calculated significant wave height may be obtained by linear interpolation based on the ship length.

2.1.5.3 The effects of wind loads may be assessed according to Chapter 5.

2.1.6 Sailing conditions

2.1.6.1 The significant value of lateral acceleration response is to be assessed when the ship is in harmonic rolling motion at different speeds and wave directions. The sailing conditions are to include:

(1) ship speed range is to include zero speed to service speed, and at least 4 intermediate speeds are to be assessed;

(2) wave directions are to include 180°(head seas), 150°, 120°and 90°, and the directions may be added as appropriate to obtain the acceleration response limits.

2.1.6.2 The significant value of lateral acceleration response is to be assessed when the ship is in parametric rolling at different speeds and wave directions. The sailing conditions are to include:

(1) ship speed range is to include zero speed to service speed, and at least 4 intermediate speeds are to be assessed;

(2) wave directions are to include head and following.

Section 2 TANK TEST PREDICTION METHOD

2.2.1 Tank tests

2.2.1.1 Tank tests are to be conducted by ITTC member units to measure the acceleration response of the ship under harmonic rolling motion and parametric rolling, and the tests are to be witnessed by ISC surveyors.

2.2.1.2 The harmonic rolling motion model test is to adopt the self-propulsion model test technology.

2.2.1.3 The motion response measurement is to adopt inertial or optical measurement system.

2.2.1.4 The ship model is to adopt an appropriate scaling ratio to reduce the impact of scaling effect. The scaling ratio is not to be less than 130, and the length between the model perpendiculars is not to be less than 2.5 m. The interference of the tank wall effect on the test is to be avoided effectively.

2.2.1.5 The model tolerance is to meet the following requirements:

(1) The quality tolerance is to be less than 1%;

(2) The initial heeling angle tolerance is to be less than 0.5°;

(3) The roll natural period is to be measured at least 3 times, and the tolerance between the mean and the target value is to be less than 2%, and the initial heeling angle is to be taken as 10° (the tolerance is to be less than ±0.5°);

(4) The initial heeling angle is to be taken as 1° (the tolerance is to be less than ±0.25°). The tolerance between the mean measured GM value and the target GM value is to be less than 2%. When measuring the GM value, the press iron is to be placed in the fixed position on the side corresponding to the center of gravity, and at least three measurements are to be carried out to obtain the mean value.

Section 3 NUMERICAL CALCULATION PREDICTION METHOD

2.3.1 Numerical calculation of harmonic rolling motion

2.3.1.1 A software/program based on the potential flow theory method or the viscous flow theory method is to be used to carry out the numerical calculation, and at least three degrees of freedom of roll, pitch and heave are to be considered. The spectrum analysis method is allowed to calculate the significant value of lateral acceleration.

2.3.1.2 For the significant value of of ship's lateral acceleration generated by harmonic rolling motion in irregular waves, the tolerance is to be controlled within ± 25% when comparing the predicted results with those obtained from model tests.

2.3.1.3 Calculation software/programs based on potential flow theory generally include but are not limited to the following methods:

(1) Frequency domain ship motion prediction method based on frequency domain Green function;

(2) Weak nonlinear ship motion prediction method in time domain based on impulse response function theory and frequency domain Green function;

(3) Time-domain linear ship motion prediction method based on time-domain Green function matching method;

(4) Time-domain weak nonlinear ship motion prediction method based on time-domain Green function matching method.

The effects of viscous effects on ship roll damping are to be considered and the roll damping is to be assessed according to the requirements of Chapter 4.

2.3.1.4 Available software/programs based on viscous flow theory methods include: full nonlinear three-dimensional CFD ship motion prediction method based on finite volume method.

2.3.1.5 Software/programs other than those specified in 2.3.1.3 and 2.3.1.4 of this Chapter may be used to perform numerical calculations subject to ISC approval.

2.3.2 Numerical calculation of parametric rolling

2.3.2.1 A software/program based on the potential flow theory method or the viscous flow theory method is to be used to carry out numerical calculation, and at least the degree of freedom of roll is to be considered. The equivalent wave theory is allowed to predict the parametric rolling response in irregular waves.

2.3.2.2 Calculation software/programs based on potential flow theory generally include but are not limited to the following methods:

(1) Time domain ship motion prediction method based on simplified single degree of freedom model;

(2) Weak nonlinear ship motion prediction method in time domain based on impulse response function theory and frequency domain Green function;

(3) Time-domain weak nonlinear ship motion prediction method based on time-domain Green function matching method.

The effects of viscous effects on ship roll damping are to be considered and the roll damping is to be assessed according to the requirements of Chapter 4.

2.3.2.3 Available software/programs based on viscous flow theory methods include: full nonlinear three-dimensional CFD ship motion prediction method based on finite volume method.

2.3.2.4 Software/programs other than those specified in 2.3.2.2 and 2.3.2.3 of this Chapter may be used to perform numerical calculation subject to ISC approval.

CHAPTER 3 MOMENTS OF INERTIA OF SHIPS

Section 1 GENERAL PROVISIONS

3.1.1 General requirements

3.1.1.1 The moment of inertia has a significant impact on the ship's motion response characteristics, and the moment of inertia is to be accurately assessed for acceleration assessment under different loading conditions, where the roll moment of inertia has a significant impact on the assessment accuracy of lateral acceleration of container ships.

Section 2 DIRECT CALCULATION METHOD OF MOMENT OF INERTIA

3.2.1 Moment of inertia under loading conditions

3.2.1.1 The sum of the moment of inertia and the additional moment of inertia of each loading condition of the ship includes five components: lightship moment of inertia, moment of inertia of liquids, moment of inertia of cargoes, moment of inertia of personnel and spare parts and the additional moment of inertia.

3.2.2 Lightship moment of inertia

3.2.2.1 The ship structure and equipment composing the lightship are to be scattered and the moment of inertia is to be calculated by analytical method, where marine equipment can be properly simplified based on its volume and mass. Figure 3.2.2.1 shows a lightship scatter model.

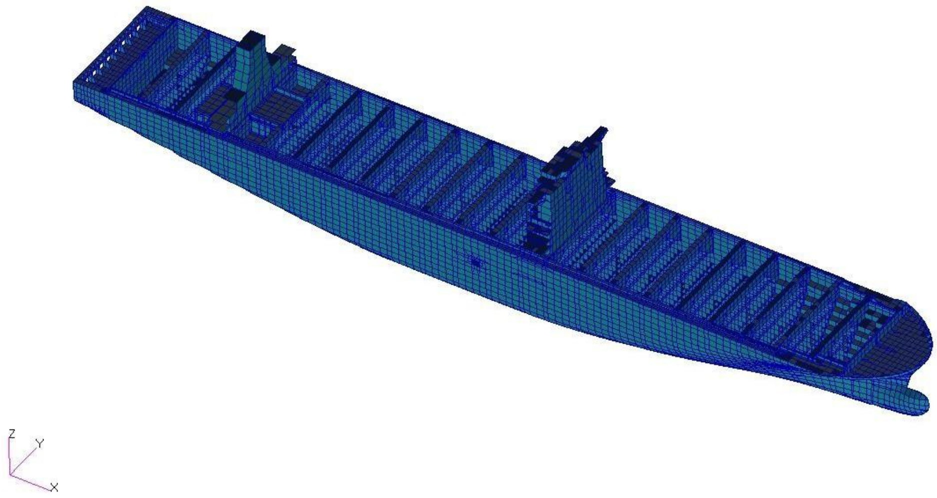

Figure 3.2.2.1 Illustration of lightship scatter model

3.2.2.2 In the absence of the results of the scatter model of the target ship, the empirical formulae based on the results of the lightship scatter model of the moment of inertia of the container ship can be used to calculate the lightship moment of inertia of the target ship. The empirical formulae are as follows:

$$I_{xx} = \Delta \cdot R_{xx}^2 \quad R_{xx} = R_x \cdot B$$
$$I_{yy} = \Delta \cdot R_{yy}^2 \quad R_{yy} = R_y \cdot L$$
$$I_{zz} = \Delta \cdot R_{zz}^2 \quad R_{zz} \approx R_{yy}$$
$$R_x = c_1 + c_2 \cdot (B/d) + c_3 \cdot (L/100)$$
$$R_y = c_4 + c_5 \cdot (B/d) + c_6 \cdot (L/100)$$

where: I_{xx}, I_{yy}, I_{zz}——dry roll, pitch and yaw moment of inertia, in $t \cdot m^2$;
Δ——volume of lightship displacement, in t;
R_{xx}——dry roll radius of gyration around axis, in m;
R_{yy}——dry pitch radius of gyration around axis, in m;
R_{zz}——dry yaw radius of gyration around axis, in m;
B——moulded breadth, in m;
L——ship length, in m;
d——mean lightship draught, in m;
R_x, R_y——moment of inertia radius coefficient;
$c_1, c_2, c_3, c_4, c_5, c_6$——approximation coefficients.

3.2.3 Moment of inertia of liquids

3.2.3.1 After the cabin volume is scattered, the moment of inertia corresponding to the liquid loading rate of each tank under loading conditions is to be calculated. The moment of inertia of liquids does not take into account the sloshing effect of liquids inside the tank. Figure 3.2.3.1 shows the scatter grid diagram of the ballast tank.

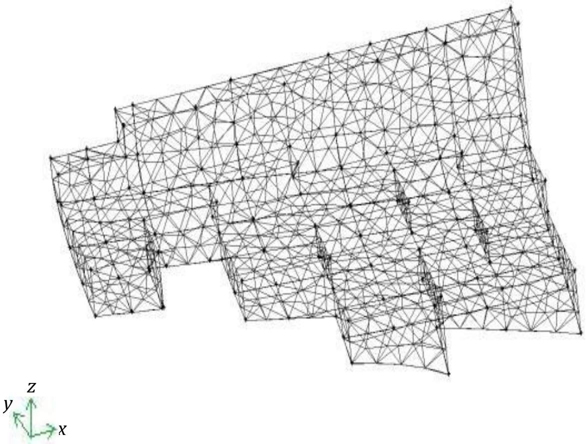

Figure 3.2.3.1 Scatter grid diagram of the ballast tank

3.2.4 Moment of inertia of cargoes

3.2.4.1 The moment of inertia of the container is to be calculated analytically according to its loading position, and the moment of inertia of all container stackings can also be calculated according to the displacement, where the cargoes in the container can be assumed to be evenly distributed in mass. Figure 3.2.4.1 shows the container stacking diagram.

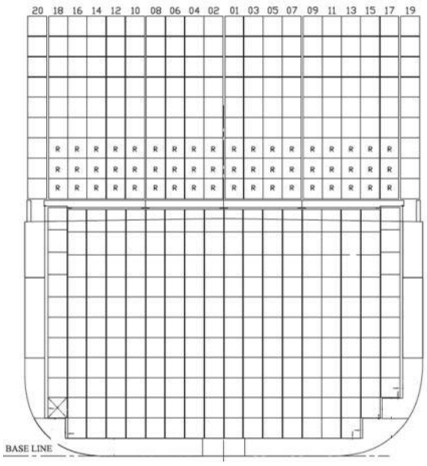

Figure 3.2.4.1 Container stacking diagram

3.2.5 Moment of inertia of personnel and spare parts

3.2.5.1 The moment of inertia of personnel and spare parts of the container under loading condition can be treated as the centralized mass.

3.2.6 Additional moment of inertia

3.2.6.1 The additional moment of inertia of the loading condition can be calculated directly by using the three-dimensional potential flow theory method. When using the time-domain ship motion prediction method of simplified single-degree-of-freedom model for numerical calculation of parametric rolling acceleration, it can also be obtained by simulating the free decay of roll by model test or the verified CFD method.

CHAPTER 4 ROLL DAMPING OF SHIPS

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 When the software/program based on potential flow theory is used to assess the acceleration response of container ships, the precision of roll damping plays an important role in the prediction of lateral acceleration response. The impact of viscous effect on roll damping is to be considered.

Section 2 METHOD FOR OBTAINING SHIP ROLL DAMPING

4.2.1 General requirements

4.2.1.1 Roll damping for ship loading is to be obtained by model test or numerical simulation using an approved viscous flow based computational fluid dynamics (CFD) in the form of free roll attenuation in still water.

4.2.1.2 The acquisition of ship roll damping is to meet the following requirements:

(1) For the numerical calculation of harmonic rolling motion, the initial heeling angle of free attenuation of roll is to be greater than 15°, and the equivalent linear roll damping coefficient can be obtained from the roll attenuation curve, or the form of linear roll damping coefficient δ_1 and third-order roll damping coefficient δ_3 can be used;

(2) For the numerical calculation of parametric rolling, the initial heeling angle of free attenuation is to be greater than 25°, and the linear roll damping coefficient δ_1 and the third-order roll damping coefficient δ_3 can be obtained from the roll attenuation curve;

(3) When the roll damping coefficient is obtained by model test, the roll free attenuation test for each loading condition is to be carried out at least 4 times with different initial heeling angles;

(4) The impact of the active anti-rolling devices is not to be considered when the roll damping coefficient is obtained. Roll damping coefficients may be included in the effect of non-active anti-rolling devices other than bilge keels, provided that sufficient evidence is submitted to justify the calculation method adopted and is approved;

(5) The roll damping under loading conditions obtained by the above methods is to be provided in the "Direct assessment report of container ship acceleration response" with test/simulation methods and calculation results.

4.2.1.3 In the absence of model test and CFD simulation results, the roll damping coefficient can be obtained by using the empirical formulae calculation method given in 4.2.2 of this Chapter.

4.2.2 Roll damping empirical formula calculation method

4.2.2.1 In the absence of model tests or approved CFD simulation results, the following empirical formulae methods are allowed to estimate the roll damping coefficient for numerical calculation of partial or fully loaded conditions:

(1) For zero-speed conditions, the components of ship roll damping include friction damping B_F, wave damping B_W, vortex damping B_E and bilge keel damping B_{BK}. In the case of speed

conditions, lift damping B_L is also to be considered. The equivalent linear damping coefficient B_{44} is represented as a function $B_{44}(\phi_a)$ of the roll amplitude ϕ_a.

$$B_{44} = B_F + B_W + B_E + B_L + B_{BK}$$

The dimensionlessness of the roll damping coefficient B_{44} and the natural roll circular frequency $\omega = 2\pi / T_r$ corresponding to the loading condition adopts the following formula:

$$\widehat{B}_{44} = \frac{B_{44}}{\rho \nabla B^2} \sqrt{\frac{B}{2g}}$$

$$\widehat{\omega} = \omega \sqrt{\frac{B}{2g}}$$

(2) For the numerical calculation of harmonic rolling motion, the roll amplitude $\varphi_a = 15^\circ$ may be taken to calculate B_{44}, and B_e may be obtained by $B_{44} = B_e$;

(3) For the numerical calculation of harmonic rolling motion, alternatively, the roll amplitude $\phi_a = 1^\circ$ may be taken to calculate B_{44}, and δ_1 can be obtained by $B_{44} = \delta_1 \cdot (I_{xx} + \Delta I_{xx})$; the roll amplitude $\varphi_a = 15^\circ$ may be taken to calculate B_{44}, and δ_3 may be obtained by $B_{44} = \delta_1 \cdot (I_{xx} + \Delta I_{xx}) + \frac{3}{4}\delta_3 \cdot (I_{xx} + \Delta I_{xx}) \cdot \varphi_a^2 \cdot \omega^2$;

(4) For the numerical calculation of parametric rolling, the roll amplitude $\phi_a = 1^\circ$ may be taken to calculate B_{44}, and δ_1 can be obtained by $B_{44} = \delta_1 \cdot (I_{xx} + \Delta I_{xx})$; the roll amplitude $\phi_a = 25^\circ$ may be taken to calculate B_{44}, and δ_3 may be obtained by $B_{44} = \delta_1 \cdot (I_{xx} + \Delta I_{xx}) + \frac{3}{4}\delta_3 \cdot (I_{xx} + \Delta I_{xx}) \cdot \phi_a^2 \cdot \omega^2$;

4.2.2.2 The friction damping B_F, wave damping B_W, vortex damping B_E, bilge keel damping B_{BK} and lift damping B_L are to be calculated as follows:

(1) The application of the empirical formulae is:

$$0.5 \leq C_b \leq 0.85$$

$$2.5 \leq B/d \leq 4.5$$

$$-1.5 \leq \frac{OG}{d} \leq 0.2$$

$$0.9 \leq C_m \leq 0.99$$

$$0.01 \leq b_{BK}/B \leq 0.06$$

$$0.05 \leq l_{BK}/L_{BP} \leq 0.4$$

$$\hat{\omega} \leq 1.0$$

When the empirical formulae are used to estimate roll damping, if the ship parameters are out of the application, the boundary values are to be taken directly for calculation.

(2) The friction damping may be calculated as follows when the speed is zero:

$$B_F = \frac{4}{3\pi} \rho s_f r_f^3 \phi_a \omega c_f$$

where: ρ ——density of salt water, taken as 1025, in kg · m^3;

c_f——friction factor;

r_f——mean radius of roll axis, in m;

s_f——wet surface area, in m^2.

The related coefficients are calculated as follows:

$$c_f = 0.74\frac{\sqrt{T_r\, v}}{r_f\, \phi_a}$$

$$r_f = \frac{(0.887 + 0.145C_b)\cdot(1.7d + C_bB) - 2\cdot OG}{\pi}$$

$$s_f = L(1.75d + C_bB)$$

where: ϕ_a——roll amplitude, in rad;

v——viscosity coefficient of seawater movement, in m^2/s;

C_b——block coefficient under loading condition;

B——moulded breadth, in m;

L——ship length, in m;

d——mean draught under loading condition, in m;

OG—Distance from still water to center of gravity (positive towards the water), in m, to be taken as $OG = d - KG$;

KG——height of center of gravity under loading condition, in m.

(3) The wave damping may be calculated as follows when the speed is zero:

$$\hat{B}_W = \frac{A_1}{\hat{\omega}}\cdot\exp\left(-0.6944A_2\left(\log(\hat{\omega}) - A_3\right)^2\right)$$

The related coefficients are calculated as follows:

$$x_1 = B/d\ ;\ x_2 = C_b\ ;\ x_3 = C_m\ ;\ x_4 = 1 - OG/d$$

$$A_1 = AA_1\cdot\sum_{i=1}^{3}\sum_{j=1}^{4}\sum_{k=1}^{5}Q1_{j+4(i-1),k}\,x_1^{5-k}x_2^{4-j}x_4^{3-i}$$

$$AA_1 = 1.0 + (1 - x_4)\cdot\sum_{i=1}^{2}\sum_{j=1}^{3}\sum_{k=1}^{5}Q1_{j+3(i-1)+12,k}\,x_1^{5-k}x_2^{3-j}x_3^{2-i}$$

$$A_2 = \sum_{i=1}^{5}Q2_i\,x_4^{5-i}$$

The coefficients Q1 and Q2 are obtained from Table 4.2.2.2(3)a. The first subscript of the coefficient Q1 is the row number of Table 4.2.2.2(3)a, and the second subscript is the column number of Table 4.2.2.2(3)a. The subscripts of the coefficient Q2 is the column number in Table 4.2.2.2(3)a.

Coefficients Q1 and Q2 Table 4.2.2.2(3)a

Coefficient Q1					
	1	2	3	4	5
1	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.00000	−0.00222	0.04087	−0.28687	0.59942
3	0.00000	0.01019	−0.16118	0.90499	−1.64139
4	0.00000	−0.01542	0.22037	−1.08499	1.83417
5	−0.06287	0.49893	0.52735	−10.79187	16.61633

6	0.11407	−0.81090	−2.21868	25.12697	−37.77298
7	−0.05893	0.26397	3.19497	−21.81266	31.41135
8	0.01077	0.00187	−1.24941	6.94279	−10.20190
9	0.00000	0.19221	−2.78746	12.50785	−14.76486
10	0.00000	−0.35056	5.22235	−23.97485	29.00785
11	0.00000	0.23710	−3.53506	16.36838	−20.53991
12	0.00000	−0.06712	0.96636	−4.40754	5.89470
13	0.00000	17.945	−166.294	489.799	−493.142
14	0.00000	−25.507	236.275	−698.683	701.494
15	0.00000	9.077	−84.332	249.983	−250.787
16	0.00000	−16.872	156.399	−460.689	463.848
17	0.00000	24.015	−222.507	658.027	−660.665
18	0.00000	−8.56	79.549	−235.827	236.579
Coefficient Q2					
	0.00000	−1.402	7.189	−10.993	9.45

$$A_3 = AA_3 + \sum_{i=1}^{7}\sum_{j=1}^{7} Q3_{i,j} x_2^{7-j} x_4^{7-i}$$

$$AA_3 = \sum_{i=1}^{4} Q4_{1,i} x_1^{4-i} \cdot \sum_{j=1}^{2}\sum_{k=1}^{4} Q4_{j+1,k} x_2^{4-k} x_4^{2-j}$$

$$\cdot \left(\sum_{i=1}^{10} Q5_i \left(x_4 - \sum_{j=1}^{4} Q4_{4,j} x_1^{4-j} \right)^{10-i} + \sum_{i=1}^{3} Q5_{i+9} x_1^{3-i} \right)$$

Coefficient Q3 is obtained from Table 4.2.2.2(3)b. The first subscript of the coefficient is the row number of Table 4.2.2.2(3)b, and the second subscript is the column number of Table 4.2.2.2(3)b. Coefficients Q4 and Q5 are obtained from Table 4.2.2.2(3)c. The first subscript of the coefficient Q4 is the row number of Table 4.2.2.2(3)c, and the second subscript is the column number of Table 4.2.2.2(3)c.

Coefficient Q3 Table 4.2.2.2(3)b

Coefficient Q3							
	1	2	3	4	5	6	7
1	−7686.0287	30131.5678	−49048.9664	42480.7709	−20665.147	5355.2035	−577.8827
2	61639.9103	−241201.0598	392579.5937	−340629.4699	166348.6917	−43358.7938	4714.7918
3	−130677.4903	507996.2604	−826728.7127	722677.104	−358360.7392	95501.4948	−10682.8619
4	−110034.6584	446051.22	−724186.4643	599411.9264	−264294.7189	58039.7328	−4774.6414
5	709672.0656	−2803850.2395	4553780.5017	−3888378.9905	1839829.259	−457313.6939	46600.823
6	−822735.9289	3238899.7308	−5256636.5472	4500543.147	−2143487.3508	538548.1194	−55751.1528
7	299122.8727	−1175773.1606	1907356.1357	−1634256.8172	780020.9393	−196679.7143	20467.0904

Coefficients Q4 and Q5 Table 4.2.2.2(3)c

Coefficient Q4				
	1	2	3	4
1	−0. 3767	3. 39	−10. 356	11. 588
2	−17. 109	41. 495	−33. 234	8. 8007
3	36. 566	−89. 203	71. 8	−18. 108
4	0	−0. 0727	0. 7	−1. 2818
Coefficient Q5				
下标	1	2	3	4
Q5	−1. 05584	12. 688	−63. 70534	172. 84571
下标	5	6	7	8
Q5	−274. 05701	257. 68705	−141. 40915	44. 13177
下标	9	10	11	12
Q5	−7. 1654	−0. 0495	0. 4518	−0. 61655

(4) The vortex damping may be calculated as follows when the speed is zero:

$$\hat{B}_E = \frac{4\hat{\omega}\varphi_a}{3\pi x_2 \cdot {x_1}^3} C_R$$

The related coefficients are calculated as follows:

$$x_1 = B/d \;;\; x_2 = C_b \;;\; x_3 = C_m$$

$$C_R = A_E \cdot \exp\left(B_{E1} + B_{E2} \cdot {x_3}^{B_{E3}}\right)$$

$$A_E = (-0.0182x_2 + 0.0155) \cdot (x_1 - 1.8)^3 + \sum_{i=1}^{5} Q6_{1,i} x_2^{5-i}$$

$$B_{E1} = (-0.2x_1 + 1.6) \cdot (3.98x_2 - 5.1525) \frac{OG}{d} \left(\frac{OG}{d} \sum_{i=1}^{3} Q6_{2,i} x_2^{3-i} + \sum_{i=1}^{2} Q6_{2,i+3} x_2^{2-i} \right)$$

$$B_{E2} = \left(0.25\frac{OG}{d} + 0.95\right) \cdot \frac{OG}{d} + \sum_{i=1}^{5} Q6_{3,i} x_2^{5-i}$$

$$B_{E3} = (46.5 - 15x_1) \cdot x_2 + 11.2x_1 - 28.6$$

Coefficient Q6 is obtained from Table 4.2.2.2(4). The first subscript of the coefficient is the row number of Table 4.2.2.2(4), and the second subscript is the column number of Table 4.2.2.2(4).

Coefficient Q6 Table 4.2.2.2(4)

Coefficient Q6					
	1	2	3	4	5
1	−79. 414	215. 695	−215. 883	93. 894	−14. 848
2	0. 9717	−1. 55	0. 723	0. 04567	0. 9408
3	0	−219. 2	443. 7	−283. 3	59. 6

(5) The bilge keel damping may be calculated as follows when the speed is zero:

$$\hat{B}_{BK} = A_{BK} \cdot \widehat{\omega} \cdot \exp\left(B_{BK1} + B_{BK2} \cdot {x_3}^{B_{BK3}}\right)$$

The related coefficients are calculated as follows:

$$x_1 = B/d \;;\; x_2 = C_b \;;\; x_3 = C_m$$

$$x_6 = \phi_a\ (\mathrm{deg})\ ;\quad x_7 = \frac{b_{BK}}{B}\ ;\quad x_8 = \frac{l_{BK}}{L}$$

$$A_{BK} = f_1 \cdot f_2 \cdot f_3;$$

$$f_1 = (x_1 - 2.83)^2 \sum_{i=1}^{3} Q7_{1,i} x_2^{3-i} + \sum_{i=1}^{3} Q7_{2,i} x_2^{3-i};$$

$$f_2 = \sum_{i=1}^{3} Q7_{3,i} x_6^{3-i};$$

$$f_3 = \sum_{i=1}^{2}\sum_{j=1}^{3} Q7_{3+i,j} x_7^{3-j} x_8^{3-i}$$

$$B_{BK1} = \frac{OG}{d} \cdot \left(5x_7 + 0.3x_1 - 0.2x_8 + \sum_{i=1}^{3} Q7_{6,i} x_6^{3-i}\right)$$

$$B_{BK2} = -15x_7 + 1.2x_2 - 0.1x_1 + \sum_{i=1}^{3} Q7_{7,i} \left(\frac{OG}{d}\right)^{3-i}$$

$$B_{BK3} = 2.5\frac{OG}{d} + 15.75$$

where: b_{BK}——breadth of the bilge keel, in m;

l_{BK}——length of the bilge keel, in m.

Coefficient Q 7 is obtained from Table 4.2.2.2(5). The first subscript of the coefficient Q 7 is the row number of Table 4.2.2.2(5), and the second subscript is the column number of Table 4.2.2.2 (5).

Coefficient Q7　　　　Table 4.2.2.2(5)

Coefficient Q7			
	1	2	3
1	0	−0.3651	0.3907
2	0	−2.21	2.632
3	0.00255	0.122	0.4794
4	−0.8913	−0.0733	0
5	5.2857	−0.01185	0.00189
6	0.00125	−0.0425	−1.86
7	−0.0657	0.0586	1.6164

(6) The lift damping may be calculated as follows when the speed is above zero:

$$\hat{B}_L = \frac{S_L U K_n l_0 l_R}{2\nabla B^2}\left(1 - 1.4\frac{OG}{l_R} + 0.7\frac{OG^2}{l_0 l_R}\right)\sqrt{\frac{B}{2g}}$$

The related coefficients are calculated as follows:

$$K_n = \frac{2\pi d}{L_{BP}} + \kappa\left(4.1\frac{B}{L_{BP}} - 0.045\right)$$

$$S_L = L_{BP} d,\quad l_0 = 0.3d\ ,\quad l_R = 0.5d,\quad U = F_n\sqrt{L_{BP} g}$$

$$\kappa = \begin{cases} 0 & C_m \le 0.92 \\ 0.1 & 0.92 < C_m \le 0.97 \\ 0.3 & 0.97 < C_m \end{cases}$$

4.2.2.3 Where the empirical formulae other than 4.2.2.2 in this Chapter are used, sufficient evidences are to be submitted in the Direct assessment report of container ship acceleration response to prove the robustness of the empirical formulae used.

CHAPTER 5   WIND LOADS

Section 1   GENERAL PROVISIONS

5.1.1   General requirements

5.1.1.1   When a large number of containers are loaded on the deck of a container ship, the effect of wind loads may lead to an increase in the rolling response of harmonic rolling motion and a decrease in the critical wave height of parametric rolling. It is recommended that the assessment accuracy of lateral acceleration of container ships may be improved by considering wind loads.

5.1.1.2   If the effect of wind loads on the acceleration response of container ships is considered, it can be assumed that the wind direction is inconsistent with the wave direction, and only the effect of wind loads on the degree of freedom of roll is considered. The wind direction can be simplified as beam wind.

5.1.2   Environmental conditions

5.1.2.1   Wind load assessment includes two parts: loads caused by steady wind and gust respectively. The gust speed may be calculated using the wind spectrum and is related to the steady wind speed. The calculation range of steady wind speed may be determined according to the environmental conditions of the sailing sea area and the ship length, the calculation step may be taken as 1.0 m/s, and the calculation range is recommended as follows, which may be increased or decreased according to the ship length as appropriate:

(1) For ships with a length greater than 250 m, the steady wind speed may be taken as 22.6 m/s to 26.0 m/s.

(2) For ships with a length less than 200 m, the steady wind speed may be taken as 19.0 m/s to 26.0 m/s.

(3) For ships with a length greater than or equal to 200 m and less than or equal to 250 m, the upper limit of steady wind speed calculation may be taken as 26.0 m/s, and the lower limit of steady wind speed calculation may be obtained according to the linear interpolation of the ship length.

Section 2   WIND LOAD ASSESSMENT METHOD

5.2.1   Wind load calculation

5.2.1.1   Wind loads may be calculated as follows:

$$F_4^W = 0.5\rho_{air} C_m (U_w + U(t))^2 A_L H_c$$

$$U(t) = \sum_{i=1}^{N_w} b_i \sin(\omega_i t + \varepsilon_i) \quad b_i = \sqrt{2 S_{wind}(\omega_i)\delta\omega}$$

$$S_{wind}(\omega_i) = 4K\frac{U_w^2}{\omega_i}\frac{{X_D}^2}{(1+{X_D}^2)^{4/3}}$$

$$K = 0.003 \quad X_D = 600\frac{\omega_i}{\pi U_w}$$

where: U_w, $U(t)$——mean wind speed and time domain wind speed variant in the transverse component of wind speed, in m/s;

A_L——lateral windage area of the ship, in m^2;

H_c——wind heeling lever, in m;

c_m——air drag coefficient.

5.2.1.2 The wind heeling lever may be determined by reference to the wind tunnel test method and the tank test method provided in IMO MSC.1/Circ.1200. In the absence of test results, the vertical distance from the center of the lateral windage area to 1/2 of the mean draught is to be taken.

5.2.1.3 The projected lateral area of the portion of the ship may be used as the lateral windage area of the ship.

5.2.1.4 The air drag coefficient needs to consider the effects of different wind directions and ship roll angles. For simplification, the effects of wind direction and heeling angle may be ignored and assumed to be constant. The coefficient may be measured by wind tunnel test. In the absence of test data, it can be simplified as 1.22.

CHAPTER 6 SAILING OPERATIONAL LIMITATIONS TO PREVENT THE LOSS OF CONTAINERS AT SEA

Section 1 GENERAL PROVISIONS

6.1.1 General requirements

6.1.1.1 Based on the acceleration response assessment results obtained in the Guidelines, lashing and securing loads on the deck from the bow to the stern at the typical height of the typical arrangement can be obtained, and appropriate sailing operational limitations can be developed to prevent the loss of containers. They can be used to guide the crew to plan the route reasonably, avoid the combination of sea states and sailing conditions that may lead to containers loss, and lower the risk of accidents.

6.1.1.2 The operational limitations to prevent the loss of containers may be established by either of the following means:

(1) A combination of safe sea states and sailing conditions related to the loading conditions that can prevent the loss of containers may be provided to the crew in the form of a manual;

(2) Onboard software may be used to give a combination of safe sea states and sailing conditions on board to avoid containers loss according to the loading conditions.

Section 2 SAILING OPERATIONAL LIMITATIONS

6.2.1 Sailing operational limitation manual to prevent the loss of containers

6.2.1.1 The sailing operational limitation manual to prevent the loss of containers is to comply with the following requirements:

(1) The sailing operational limitations are to be established separately according to loading conditions, including displacement, GM value, rolling moment of inertia and trim, etc.;

(2) The combination of safe sea states and sailing conditions given by sailing operational limitations is to include: significant wave height, wave direction and speed;

(3) Maximum mass of containers is to be given to prevent the loss of containers on the deck from the bow to the stern at the typical height of the typical arrangement.

6.2.2 Onboard software

6.2.2.1 Onboard software is to comply with the following requirements:

(1) The software is to be able to give the combination of safe sea states and sailing conditions according to the input loading conditions, including: significant wave height, wave direction, ship speed and wind speed.

(2) The software is to give maximum mass of the container on the deck from the bow to the stern at the typical height of the typical arrangement to prevent the loss of containers.

(3) The software is to be able to ensure that ordinary users cannot modify the actual ship data such as the ship geometric characteristics and ship type characteristics that have been entered.

(4) The software is to use a direct calculation method or an appropriate proxy model to obtain the acceleration response of the loading condition and the corresponding sailing operational

limitations.

(5) The software is to be tested based on the typical loading conditions provided in the Direct assessment report of container ship acceleration response and achieve equivalent accuracy.